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SPECKLE INTERFEROMETRY AT THE USNO FLAGSTAFF STATION: OBSERVATIONS OBTAINED IN 2008 AND NINE NEW ORBITS

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ABSTRACT

Results are presented for 299 speckle interferometric observations of double stars, obtained in 2008 at the USNO Flagstaff Station using the 1.55 m Kaj Strand Astrometric Reflector. Separations range from 0$''$.15 to 9$''$.88, with a median of 2$''$.22. This observing run concentrated on neglected systems, as well as systems in need of improved orbital elements; new orbital solutions have been determined for nine systems as a result.

Key words: binaries: general – binaries: visual – techniques: interferometric

1. INTRODUCTION

Although principally based at the historic 26 inch Clark refractor in Washington, DC (cf. Mason et al. 2010, 2011), the USNO speckle camera has on occasion been transported to other instruments in order to observe stars at declinations and/or separation regimes not accessible to the Clark. Recent tours have included the KPNO and CTIO 4 m (Tokovinin et al. 2010; Mason et al. 2009), the Mount Wilson 2.5 m (Hartkopf & Mason 2009), and the McDonald Observatory 2.1 m (Mason et al. 2001). To facilitate these numerous "off-campus" tours, a secondary speckle camera was constructed in 2006 (see Mason et al. 2007) for use on the 26 inch.

In 2003 December and again in 2004 March, the primary camera was mounted on the 1.55 m (61 inch) Kaj Strand Astrometric Reflector at the USNO Flagstaff Station (NOFS; see Hartkopf et al. 2008, henceforth Paper I) in order to test the feasibility of using this instrument as well. Following these initial runs, the camera was again mounted on the 61 inch in 2008 November for a seven-night run. Observing lists were prepared in the same manner as for the earlier NOFS runs, with a "primary" list plus a backup "secondary" list for use during periods of poorer conditions.

2. CALIBRATION AND RESULTS

The run was partially successful, with about $2\frac{1}{2}$ nights lost to weather. Due to extended periods of poor seeing, the secondary list was used for most of this tour. As a result, the median separation of observed pairs was considerably larger than during the two earlier runs. A total of 420 observations were obtained, with data reduced at the telescope in real time, using the DVA (directed vector autocorrelation) reduction technique described by Mason et al. (2001).

As in Paper I, calibration relied on observations of well-observed binaries. During this NOFS run, we obtained 47 observations of 44 binaries with well-characterized orbits or otherwise well-defined relative astrometry for this purpose. A weighted least-squares fit was made to transform between the (x, y) centroid positions of peaks in the calibration DVAs and the corresponding (ρ, θ) values predicted at the time of observation. It should be noted that calibration systems with published elements were first checked against all corresponding data in the Washington Double Star (WDS) database. Orbits were recalculated for those systems showing systematic trends in their residuals, using all available data (other than, of course, the measures being calibrated here).

The rms O − C residuals for these calibration observations are 0°.71 in position angle and 1.21% in relative separation or scale ($\delta\rho/\rho$). We take these values to represent the approximate precision of all the measures. Systems used for calibration are flagged in the tables of results described below.

After removal of poor measures and averaging of multiple observations, a total of 299 mean measures were obtained; results are given in Tables 1 and 2. Table 1 presents the results for 259 pairs without published orbital elements. Columns 1 and 2 give the WDS designation (based on epoch-2000 coordinates) and discoverer designation for each pair. Columns 3–5 give the date of observation (in fractional Besselian year), position angle θ (in degrees), and separation ρ (in arcseconds). Colons following θ and ρ indicate measures of lower quality (due to such factors as close separation, large magnitude difference, faint primary and/or secondary, large zenith distance, or poor seeing or transparency). The final two columns indicate the number of observations included in each mean measure and a flag for any notes.

Table 1 includes one new pair; the secondary of the 1$''$.4 pair WDS 21391 + 3356 = COU 1185 was resolved into a 0$''$.18 binary, which we have designated WSI 120 Ba,Bb. Both components appeared to be of similar brightness, so given the *Tycho* V_T magnitude for the B component of 10.31, the Ba and Bb components are each estimated to be of magnitude 11.1.

Table 2 presents the results for 40 pairs with published orbital elements or rectilinear fits. Here the first six columns are identical to those in the previous table, while Columns 7 and 8 give O − C orbit residuals in θ and ρ to the orbit or linear fits. Column 9 lists either the reference to the orbit or a letter "L," indicating a linear solution in the *Catalog of Rectilinear Elements*.[1] These orbits are listed in the *Sixth Catalog of Visual Orbits*[2] as being the best-published solutions available for these pairs. Flags for notes are given in Column 10. New orbital solutions (discussed below) have been determined for nine pairs; for those pairs with previously published elements the residuals from our new solutions are listed on a separate line, with blanks in the remaining columns.

3. NEW ORBITS

New orbital solutions were attempted for all systems without previously published elements whose measures indicated significant orbital motion, as well as those systems whose recent

1 http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/lin1
2 http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6

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14. ABSTRACT
Results are presented for 299 speckle interferometric observations of double stars, obtained in 2008 at the USNO Flagstaff Station using the 1.55 m Kaj Strand Astrometric Reflector. Separations range from 0. 15 to 9. 88, with a median of 2. 22. This observing run concentrated on neglected systems, as well as systems in need of improved orbital elements; new orbital solutions have been determined for nine systems as a result.

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Table 1
Speckle Interferometric Measurements of Double Stars without Orbits

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	Note
00048+4358	A 203	8.8715	347.3	1.893	1	
00057+4239	A 110	8.8715	122.7	2.100	1	
00136+4412	A 1254	8.8716	271.4	1.257	1	
00173+3332	ES 2210	8.8663	270.8	3.268	1	
00174+0853	STF 22 AB,C	8.8689	234.2	3.936	1	1
00248+1925	BRT 2296	8.8662	189.4	3.048	1	
00257+0414	J 631	8.8553	110.8	3.672	1	
00278+5001	HU 507 AB	8.8717	127.3	1.673	2	
00278+5001	HU 507 AC	8.8717	178.8	1.599	2	
00278+5001	HU 507 BC	8.8717	246.9	1.441	2	
00286+3449	J 870	8.8716	210.4	3.512	1	
00295+3137	J 871	8.8662	357.6	2.184	1	
00310+3406	STF 33	8.8663	212.6	2.752	1	1
00414+2526	J 1803	8.8662	98.0	2.464	1	
00444+3337	STF 55	8.8663	329.6	2.211	1	1
00455+4324	BU 865 AB	8.8716	192.6	1.253	1	
00481+2533	HO 306	8.8662	159.9	1.371	1	
00535+0318	HDO 37	8.8553	230.8	1.566	1	
01004+1803	BRT 1927	8.8689	171.9	1.903	1	
01007+0929	STF 82 AB	8.8690	303.8	1.765	1	
01119+4748	BU 398	8.8717	44.0	1.737	1	
01149+4815	A 934	8.8717	182.4	3.115	1	
01158+4402	BRT 78	8.8717	354.3	3.623	1	
01198−0031	STF 113 A,BC	8.8553	18.7	1.610	1	
01205+0418	J 1807	8.8690	249.9	3.096	1	
01321+1218	AG 20	8.8690	248.8	2.671	1	
01355+3118	STF 137	8.8663	84.3	3.361	1	
01390+4104	STF 140 AB	8.8718	174.1	3.387	1	
01490+4826	ES 5	8.8717	99.6	2.643	1	
01493+4754	STF 162 AB	8.8717	199.2	1.913	1	
01520+1049	STF 178	8.8690	204.2	2.976	1	1
01529+2152	J 671	8.8689	153.5	2.924	1	
01540−1413	HU 423	8.8553	119.1	1.787	1	
02002+4427	STF 195	8.8719	194.3	3.023	1	
02062+2507	STF 212	8.8665	161.4	1.894	1	
02144+3810	ES 230	8.8718	300.8	2.725	1	
02244+1130	STF 261	8.8691	251.9	2.852	1	
02262+2105	COU 258	8.8691	122.4	2.267	1	
02341−0538	STF 280	8.8556	345.1	3.610	1	
02344+1148	HLD 63	8.8691	291.9	1.375	1	
02389−0135	HO 315	8.8690	356.9	1.632	1	
02389+1526	AG 43	8.8691	61.8	2.965	1	
02411+1848	STF 291 AB	8.8691	117.3	3.390	1	1
02422+4242	STT 44 AB	8.8718	55.7	1.383	1	
02502+0641	AG 55 AB	8.8691	48.2	2.395	1	
02527+0628	STF 323	8.8691	279.7	2.791	1	1
02583+4740	J 886	8.8719	184.2	2.624	1	
03051+2755	STF 342	8.8665	303.9	3.225	1	1
03073+0824	STF 355	8.8691	144.1	2.464	1	
03102−1352	HU 605	8.8556	61.5	2.516	1	
03171+4029	STF 369	8.8719	29.8	3.586	1	1
03206+1911	STF 377 AB	8.8691	110.2	1.153	1	
03211+4322	A 1705	8.8719	7.7	3.362	1	
03248+4159	A 1288	8.8583	4.0	0.679	1	
03250+4013	HU 1058	8.8582	113.3	0.847	1	
03260+4536	HO 322	8.8719	124.7	1.858	1	
03261+2015	A 2344 AB	8.8691	193.5	1.227	1	
03307−0416	STF 408	8.8556	320.6	1.070	1	
03312+1947	STF 403	8.8691	171.8	2.321	1	1
03334−1301	HU 207	8.8556	297.1	0.966	1	
03354+3341	STF 413	8.8665	124.1	2.258	1	1
03384+1736	A 2420	8.8691	268.9	2.084	1	
03446+3551	HO 504	8.8719	192.9	1.129	1	
03454+4952	HU 103 AB	8.8584	201.4	1.150	1	
03455+0029	J 235	8.8693	261.5	2.438	1	
03466+2728	COU 694	8.8666	134.7	2.514	1	1

Table 1
(Continued)

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ (″)	n	Note
03581−0454	HLD 70	8.8557	273.5	3.472	1	
03597+1128	HU 28	8.8694	0.5	1.161	1	
04020+4151	STF 477	8.8584	211.6	3.062	1	
04024−0700	STF 489	8.8557	197.3	3.048	1	
04038+2549	COU 562	8.8666	337.5	1.845	1	
04059+1058	STF 491	8.8694	96.6	2.887	1	1
04067+0541	STF 493	8.8693	84.4	1.332	1	
04134+0252	STF 515	8.8693	38.6	3.144	1	
04216+0523	A 1836	8.8693	197.1	1.354	1	
04222−0441	STF 536	8.8557	190.1	1.506	1	
04247−0845	STF 544 AB	8.8557	351.6	3.257	1	
04331−1208	STF 564 AB	8.8557	347.1	3.388	1	
04333+5103	STF 553	8.8584	134.7	3.114	1	
04335+1801	STF 559	8.8665	277.1	3.035	1	1
04401+4220	WEI 4	8.8584	109.8	2.564	1	
04429−1758	B 1940	8.8556	19.3	1.466	1	
04464+2950	MLB 686	8.8666	241.7	2.220	1	
04465+0358	A 2425	8.8693	97.5	1.363	1	
04511−0946	HU 31	8.8557	330.7	1.292	1	
04518+0115	STF 609	8.8693	69.5	2.916	1	
04518−0751	BU 748	8.8557	128.5	1.252	1	
04526+4302	ES 1526 BC	8.8584	102.8	2.729	1	
04561+0908	BU 404	8.8694	290.2	1.692	1	
04576+1208	HEI 458	8.8694	0.8	2.587	1	
04581+0141	STF 622	8.8693	162.5	2.504	1	1
05027+3507	J 240	8.8666	210.7	1.296	1	
05042+4341	J 13	8.8721	167.5	2.024	1	
05079+0824	STF 643	8.8722	124.1	2.467	1	
05089+6749	HU 1096	8.8721	267.9	1.191	1	
05099−0906	A 483 AB	8.8560	58.2	3.830	1	
05103+3718	STF 644 AB	8.8721	222.1	1.617	1	
05125−0302	A 51	8.8558	103.2	1.434	1	
05142+5446	A 1304	8.8721	87.1	1.820	1	
05167+1826	STF 670 AB	8.8668	164.3	2.550	1	1
05172+3320	STF 666	8.8667	74.2	3.041	1	1
05177+0441	STF 678 AB	8.8722	102.6	3.574	1	
05207+3349	J 652	8.8667	355.2	3.718	1	
05217−0203	STF 693	8.8558	10.5	3.499	1	
05229−0753	OL 137	8.8560	207.9	1.604	1	
05239−0052	WNC 2 A,BC	8.8558	158.6	3.087	1	1
05247+2009	J 145	8.8667	347.5	2.709	1	
05247+3945	AG 94	8.8721	291.0	2.731	1	
05248+6444	STF 676	8.8721	267.8	1.343	1	
05263+3020	STF 706	8.8667	42.7	3.742	1	
05307+1154	A 2705	8.8694	251.7	1.021	1	
05309+1015	STF 726	8.8695	262.3	1.149	1	
05347−0424	STF 743 AB	8.8558	283.0	1.833	1	
05352+1839	J 248	8.8668	29.4	3.854	1	
05352+3358	AG 97	8.8666	269.9	2.046	2	
05381−0011	STF 757 AB	8.8558	240.0	1.458	1	
05444+2556	J 8	8.8669	252.9	2.646	1	
05452−1510	HLD 77	8.8560	294.6	2.370	1	
05457−1917	I 744	8.8560	89.1	1.387	1	
05484−1842	HJ 3799	8.8560	152.4	3.789	1	
05499+3147	STF 796 AB	8.8669	61.8	3.719	1	
05544+1854	STF 813	8.8668	150.6	3.055	1	1
05585−2010	S 504	8.8560	67.4	3.562	1	
06034+0811	J 51	8.8695	115.5	1.483	1	
06039+1015	J 310	8.8695	318.1	2.431	1	
06080+0744	J 255	8.8695	129.0	2.903	2	
06080+0744	J 255 AC	8.8695	245.8	7.443	1	
06080+2214	J 1050	8.8668	357.8	2.374	1	
06114−1650	A 3022	8.8560	359.9:	1.042:	1	
06123+1001	J 2017	8.8695	116.7	1.450	1	
06128+2426	AG 107	8.8668	178.6	1.415	1	
06129−0609	J 717 AB	8.8722	286.1	2.780	1	

Table 1
(Continued)

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	Note
06163−0633	J 685	8.8560	171.5	3.282	1	
06197+2128	AG 109	8.8723	17.0	2.313	1	
06275+2432	AG 112 AB	8.8723	208.2	2.784	1	
06283+0556	J 658	8.8696	277.5:	3.490:	1	
06288−0702	STF 919 AB	8.8560	132.4	7.103	1	
06288−0702	STF 919 AC	8.8560	125.1	9.879	1	
06288−0702	STF 919 BC	8.8560	107.5	2.970	2	
06309+0439	J 691	8.8696	204.5:	1.266:	1	
06386+2124	J 694	8.8723	316.9	3.078	1	
06410+0542	STF 949	8.8696	289.2	3.464	1	
06412−0759	STF 955 AB	8.8560	268.0:	1.179:	1	
06415+0950	STF 3118 AB	8.8696	173.3	2.704	1	
06463−2046	STN 15	8.8561	321.5:	2.483:	1	
06468+1008	J 726	8.8724	127.7	2.260	1	
06481+1828	J 1096	8.8724	330.6:	2.905:	1	
06484−1326	STF 971 AB	8.8561	323.0	1.208	1	
06504+0541	J 698	8.8696	243.6:	3.079:	1	
06543−1415	STF 990 AB	8.8561	274.8:	2.733:	1	
06545+0820	J 272	8.8723	267.5	4.092	1	
06561+2005	HO 27 AB	8.8724	126.8	3.683	1	
06586+0641	J 278	8.8696	146.8	2.397	1	
07029+2223	J 997	8.8724	156.2	2.348	1	
07057+2608	STF 1014	8.8669	219.3	1.964	1	
07061−1257	HU 48	8.8561	149.3	2.619	1	
07086−1359	STF 1031 AB	8.8561	251.0:	3.534:	1	
07142+0533	J 2039	8.8696	200.4	2.338	1	
07198+1322	STF 1068 AB	8.8698	349.4	4.046	1	
07210+0403	STF 1076	8.8698	107.8	2.904	1	
07247+1753	J 1062	8.8669	249.3	2.128	1	
07274+1519	STF 1094	8.8698	96.6	2.519	1	1
07319−0031	STF 1109 AB	8.8724	17.4	3.130	1	
07345+1218	STF 1116	8.8698	96.1	1.780	1	
07463+1344	SCJ 8	8.8698	24.9	2.285	1	
07503+2432	STF 1147	8.8669	174.4	2.177	1	
08023+1008	J 732	8.8698	191.4	2.573	1	
08047+0532	J 1001	8.8698	161.7	3.290	1	
08071+0121	STF 1185	8.8698	93.7	3.845	1	
08074+1145	J 1002	8.8698	118.0	2.251	1	
08092+1202	J 376	8.8698	283.8	2.134	1	
08122+1739	STF 1196 AC	8.8669	67.6	6.622	1	
08122+1739	STF 1196 BC	8.8669	71.7	5.748	1	
08127+2933	STF 1197	8.8671	100.1	1.780	1	
08298+5112	STF 1225	8.8726	189.4	3.682	2	
08369+2315	AG 154	8.8669	1.0	2.648	1	
08505+2308	AG 157 AB	8.8669	76.1	2.211	1	
08508+3504	STF 1282 AB	8.8699	278.0	3.529	2	1
08510+1802	BRT 2392	8.8669	87.2	3.735	1	
08542+3035	STF 1291 AB	8.8671	310.3	1.509	1	
08571+1045	A 2968	8.8698	132.7	1.162	1	
20327+4008	TDT 2351	8.8575	127.8:	0.563:	1	2
20356+3432	J 792	8.8685	321.1	3.378	1	
20356+3510	STF 2702	8.8685	205.2	3.202	1	
20411+3516	COU 1963 AB	8.8575	1.0	0.254	1	
20420+4015	A 1433	8.8575	24.3	0.761	1	
20432+4026	COU 2421	8.8575	104.5	0.308	1	
20548+3242	STT 418	8.8685	283.3	0.985	1	
21022+0711	STF 2742	8.8550	214.0	2.877	1	
21097+3856	COU 1967	8.8577	191.0	0.813	1	
21099+4013	COU 1968	8.8577	106.2	0.174	1	
21109+0352	HO 151	8.8550	16.9	1.488	1	
21110+0933	STF 2765 AB	8.8550	79.6	2.784	1	1
21139+3830	COU 1817	8.8577	108.4	0.564	1	
21197+0931	STF 2786	8.8550	187.9	2.765	1	1
21237+0422	STF 2791	8.8550	103.5	2.816	1	
21256+0248	J 1039	8.8549	331.5	4.275	1	
21256+4138	A 618	8.8577	275.9	0.543	1	

Table 1
(Continued)

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ ($\circ$)	ρ ($''$)	n	Note
21268 + 4228	A 619	8.8578	58.7	0.745	1	
21281 + 4110	COU 2231	8.8578	30.9	0.205	1	
21328 + 3904	A 1443	8.8578	245.1	0.240	1	
21349 + 0308	A 2291	8.8549	92.8	1.010	1	
21386 + 3822	TDT 3078	8.8578	156.7:	0.665:	1	2
21391 + 3356	COU 1185 AB	8.8715	55.8	1.350	1	
21391 + 3356	WSI 120 Ba,Bb	8.8715	37.8	0.180	1	3
21393 + 2043	STT 445	8.8687	120.1	1.025	1	
21399 + 1427	AG 419	8.8687	222.7	3.719	1	
21417 − 0036	J 1409	8.8552	325.8	3.538	1	
21420 + 0408	J 1790	8.8551	95.5	2.287	1	
21435 + 2721	A 299 AB	8.8687	64.6:	1.059:	1	
21455 + 2156	AG 276	8.8687	1.8	1.895	1	
21460 + 1053	BU 1305 BC	8.8551	52.9	1.246	1	
21461 + 2111	AG 277	8.8687	60.2	2.609	1	
21468 + 1030	J 201	8.8551	224.8	2.680	1	
21489 + 0523	HU 281	8.8551	145.3	1.434	2	
21495 + 0324	STF 2828 BC	8.8551	38.9	3.520	1	
21555 + 5232	STT 456 AB	8.8713	36.9	1.592	1	
21593 + 3431	J 3156	8.8715	169.3	3.017	1	
21593 + 3516	COU 1340	8.8579	185.5	0.175	1	
22013 + 4515	A 780 AB	8.8715	147.2	1.507	1	
22039 + 2406	J 1246 AB	8.8687	351.9	2.927	1	
22044 + 1339	STF 2854	8.8550	83.2	1.683	1	
22054 + 3858	A 1453	8.8579	329.0	0.529	1	
22055 + 5108	ES 1110	8.8713	2.0	2.218	1	
22058 + 0452	STF 2856	8.8551	194.0	1.204	1	
22071 + 0034	STF 2862	8.8552	95.7	2.510	2	1
22102 + 4004	A 1455	8.8715	115.3	1.039	1	
22143 + 3745	STF 2882	8.8715	147.5	3.426	1	
22146 + 2934	STF 2881	8.8687	76.7	1.303	1	
22161 + 3521	J 1211	8.8715	237.8	3.118	1	
22206 + 5349	BU 379	8.8713	333.3	1.118	1	
22245 + 0349	STF 2901	8.8553	147.8	3.204	1	
22268 + 4033	COU 1642	8.8579	97.5	0.365	1	
22334 + 3935	HDS 3200 Aa,Ab	8.8580	171.5	0.214	1	
22340 − 0147	BU 77 AB	8.8552	216.5	2.775	1	
22341 + 3823	COU 1488	8.8580	53.7	0.325	1	
22371 + 3712	A 1472	8.8580	252.7	0.229	1	
22395 + 4123	BU 277 AB	8.8580	220.4	0.428	1	
22527 + 4347	COU 2244	8.8582	281.5	0.233	1	
22588 + 3808	HDS 3272	8.8580	349.6	0.159	1	
23147 + 4116	A 200	8.8582	78.4	0.579	1	
23188 + 2513	STF 3000	8.8661	50.1	3.397	1	
23193 + 0639	J 3256	8.8553	164.0	3.627	1	
23198 + 4243	COU 1646	8.8582	79.0	0.164	1	
23208 + 2158	STT 494	8.8661	81.3	3.303	1	1
23256 + 3326	AG 292	8.8661	234.1	3.674	1	
23280 + 3333	STF 3015	8.8661	189.6	2.917	1	
23285 + 0334	BU 1222	8.8553	52.5	1.428	1	
23287 + 1157	A 1239	8.8688	53.2	2.022	1	
23292 + 4042	A 1487	8.8715	157.7	1.069	1	
23309 + 0929	STT 497	8.8688	216.3	1.352	1	
23363 + 2854	STF 3026	8.8661	273.9	3.261	1	
23392 + 3535	HO 203	8.8715	128.6	3.742	1	
23407 − 0023	STF 3030	8.8553	222.1	2.421	1	
23420 + 2018	STT 503 AB	8.8662	133.4	1.087	1	
23439 + 0715	STF 3033	8.8553	182.9	3.024	1	
23522 + 4331	BU 728 AB	8.8715	9.2	1.222	1	
23546 + 4422	BRT 1163	8.8716	8.9	3.505	1	
23572 + 3751	AG 297	8.8715	312.2	2.089	1	

Notes. 1: Pair used for calibration; see text.
2: Confirming observation.
3: New pair; see text.

Table 2
Speckle Interferometric Measurements and Residuals of Systems with Orbits or Rectilinear Fits

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	n	O−C (°)	O−C ($''$)	Reference	Note
00014+3937	HLD 60	8.8715	169.0	1.286	1	−1.0	0.048	Heintz (1963)	1
						−0.7	0.010	Table 3	
00059+1805	STF 3060 AB	8.8662	133.2	3.395	1	−0.9	0.086	L	
00521+1036	STF 67	8.8689	348.7	2.252	1	−1.7	−0.011	Table 3	
01017+4635	A 927	8.8717	7.9	2.410	1	−0.3	−0.043	L	
01052+4354	A 1810	8.8717	182.2	2.950	1	0.1	−0.031	L	
01360+0739	STF 138 AB	8.8690	57.8	1.694	1	−0.3	−0.005	L	
01467+3310	STF 158 AB	8.8663	269.3	2.193	1	−2.8	0.123	Table 3	1
01532+1526	BU 260	8.8690	258.8	1.110	1	−0.7	0.013	Cvetković & Novaković (2006)	1
02284+1722	A 2330	8.8691	203.9	1.207	1	−1.2	−0.016	L	
02327+0620	STF 276	8.8691	273.5	1.824	1	0.4	−0.039	L	
02446+2928	STF 300	8.8665	314.5	3.162	1	−0.3	−0.007	L	1
02475+1922	STF 305 AB	8.8691	307.4	3.656	1	0.9	−0.063	Rabe (1961)	1
03005+3934	A 1530	8.8582	76.4	0.274	1	4.3	0.004	Table 3	
03177+3838	STT 53	8.8582	242.2	0.652	1	−0.3	0.005	Alzner (1998)	1
04367+1930	STF 567	8.8666	343.0	2.000	1	1.3	−0.035	Seymour et al. (2002)	1
05005+0506	STT 93	8.8693	243.1	1.497	1	−1.0	0.019	Seymour & Mason (1999)	1
05148+1232	HU 1224	8.8694	115.3	1.031	1	0.1	−0.001	Table 3	
05371+2655	STF 749 AB	8.8667	320.4	1.157	1	−1.0	−0.003	Scardia et al. (2007)	1
05474+2939	BU 560	8.8669	125.4	1.668	1	−0.3	0.014	Scardia et al. (2008)	1
07128+2713	STF 1037 AB	8.8669	309.2	1.037	1	−0.5	−0.002	Söderhjelm (1999)	1
08095+3213	STF 1187 AB	8.8671	22.2	3.002	1	1.0	0.072	Olević & Jovanović (2001)	1
08122+1739	STF 1196 AB	8.8669	42.9	1.036	2	0.8	−0.005	Mason et al. (2006)	1
08507+0752	VDK 3	8.8698	164.4	1.436	1	−0.4	0.075	Mason et al. (2006)	1
20396+4035	STT 410 AB	8.8575	4.3	0.864	1	0.0	0.004	Table 3	
21031+0132	STF 2744 AB	8.8549	113.0	1.272	1	5.0	0.060	Popović (1969)	
21171+4001	A 1441 AB	8.8577	278.0	0.151	1	−1.3	−0.005	L	
21208+3227	STT 437 AB	8.8685	19.9	2.403	1	−0.1	0.004	Table 3	1
21289+1105	STF 2799 AB	8.8550	261.3	1.864	1	2.1	0.128	Popović (1987)	1
						0.3	0.023	Table 3	
21362+4253	HO 463	8.8578	178.6	0.483	1	−0.5	−0.013	L	
21424+4105	KUI 108	8.8578	56.3	0.161	1	2.7	0.002	Hartkopf & Mason (2000)	
21426+4103	BU 688 AB	8.8578	200.1	0.409	1	−0.7	−0.029	Brendley & Hartkopf (2006)	1
21556+3849	A 1449	8.8578	58.4	0.272	1	7.4	−0.027	Baize (1993)	
22113+4010	STT 464 AB	8.8579	179.3	0.310	1	−5.8	0.012	Ling & Prieto (1999)	
22116+4056	A 409	8.8579	13.6	0.402	1	−0.1	−0.002	L	
22288−0001	STF 2909 AB	8.8552	169.6	2.083	1	−3.3	−0.027	Scardia et al. (2010)	
22308+4007	A 1467	8.8580	272.5	0.306	1	−0.3	−0.003	L	
22402+3732	HO 188	8.8580	223.9	0.365	1	−0.1	0.018	Brendley & Mason (2006)	1
23114+3813	HO 197 AB	8.8582	281.7	0.196	1	−5.7	0.005	Rica Romero (2010)	
23133+2205	STF 2990 AB	8.8661	56.1	2.512	1	0.2	0.006	L	1
23595+3343	STF 3050 AB	8.8661	334.7	2.212	1	−0.5	0.116	Starikova (1977)	1
						−0.8	−0.017	Table 3	

Note. 1: Pair used for calibration; see text.

measures showed considerable residuals from published elements. The "grid search" method used for these calculations is described by Hartkopf et al. (1989), with the weighting system for individual observations described by Hartkopf et al. (2001). A total of nine systems yielded new solutions that were deemed sufficiently improved for publication. Elements for these systems are given in Table 3, where Columns 1 and 2 give the WDS and discoverer designations and Columns 3–9 list the seven Campbell elements: P (period, in years), a (semimajor axis, in arcseconds), i (inclination, in degrees), Ω (longitude of node, equinox 2000, in degrees), T_0 (epoch of periastron passage, in fractional Besselian year), e (eccentricity), and ω (longitude of periastron, in degrees). Formal errors are listed below each element. Column 10 gives a rough grade for each orbit (where 1 = "definitive" and 5 = "indeterminate"), as described by Hartkopf et al. (2001) and based on similar grading schemes used in earlier orbit catalogs. Finally, Column 11 gives a reference for the previous "preferred" published orbit currently listed in the *Sixth Orbit Catalog*.

Figure 1 shows the new orbital solutions, plotted with all published data in the WDS database. In each of these figures, micrometric observations are indicated by plus signs, interferometric measures by filled circles or (for the new USNO measures) filled stars, *Hipparcos* and *Tycho* measures by the letters "H" or "T." "O − C" lines connect each measure to its predicted position along the new orbit (shown as a thick solid line). A dot-dashed line indicates the line of nodes, and a curved arrow in the lower right corner of each figure indicates the direction of orbital motion. Previous published orbits are shown as dashed ellipses; references to each of the published orbits are given in the final column of Table 3.

Table 4 gives ephemerides for each orbit over the years 2012.0 through 2022.0, in two-year increments. Columns 1 and 2 are the same identifiers as in the previous table, while Columns

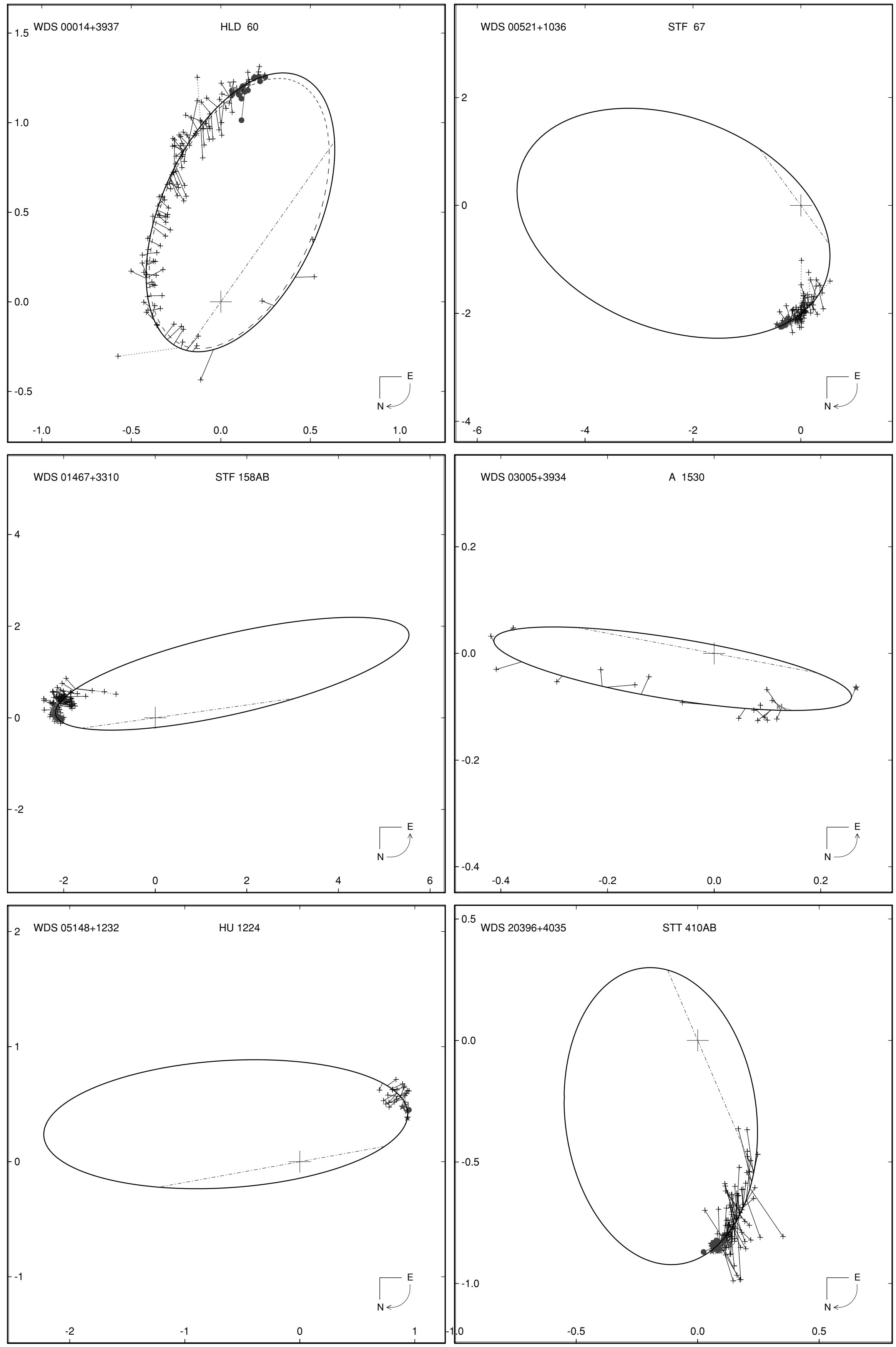

Figure 1. New orbits for the systems listed in Table 3, together with all published data in the WDS database. See text for a description of symbols used in this and the following figure.

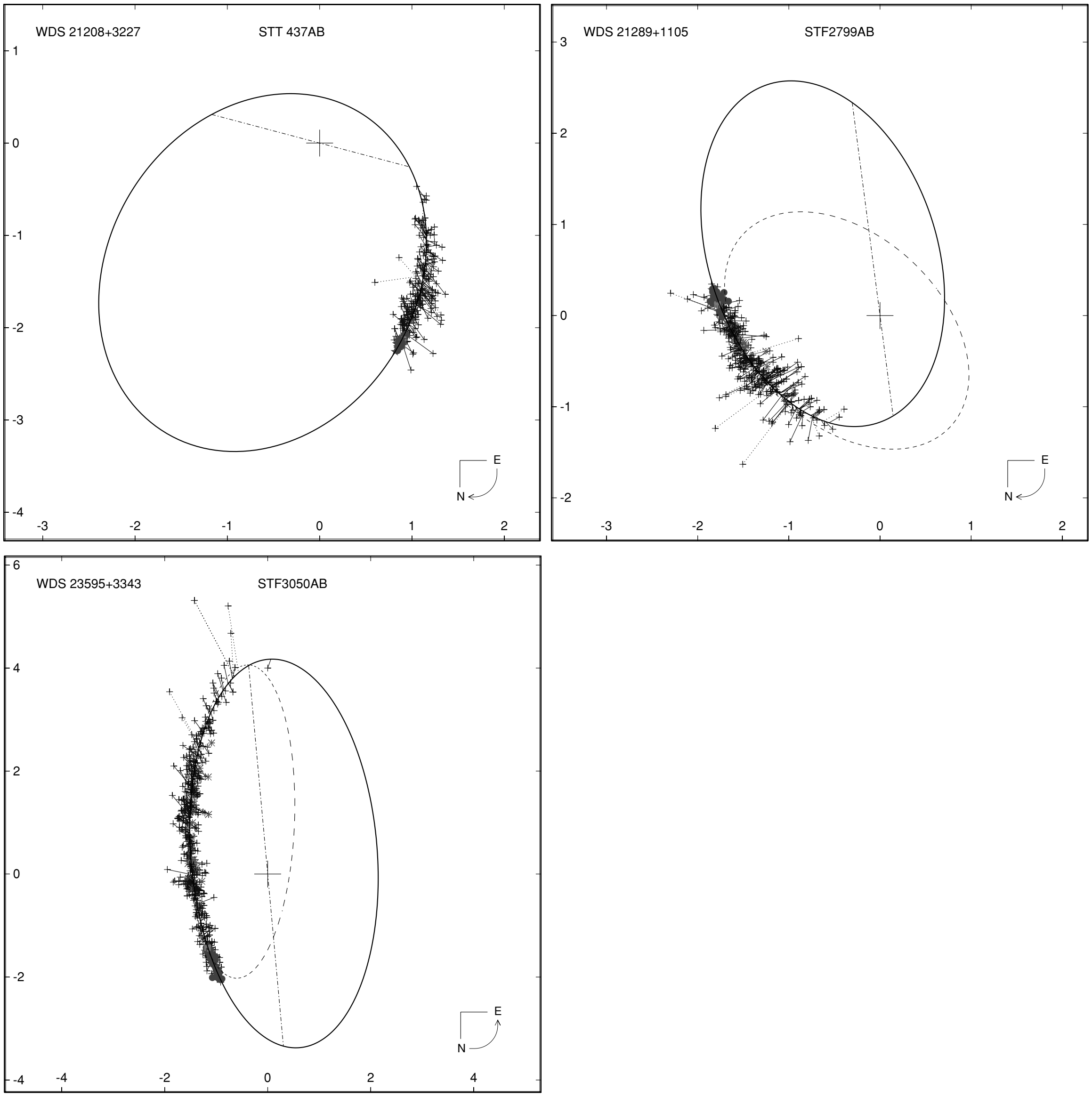

Figure 1. (Continued).

Table 3
New Orbital Elements

WDS Desig. (Figure No.)	Discoverer Designation	P (yr)	a ($''$)	i ($\circ$)	Ω ($\circ$)	T_o (yr)	e	ω ($\circ$)	Gr	Published Orbit Reference
00014 + 3937	HLD 60	223.2	0.8798	128.3	324.7	1903.08	0.6479	325.7	3	Heintz (1963)
(1a)		±12.2	±0.0039	±2.8	±2.2	±1.28	±0.0123	±3.8		
00521 + 1036	STF 67	4133.	5.982	113.3	216.	1741.	0.908	102.0	5	···
(1b)		±5388.	±0.085	±11.3	±25.	±54.	±0.078	±11.5		
01467 + 3310	STF 158 AB	2239.	5.351	78.8	278.	2089.7	0.764	65.	5	···
(1c)		±9999.	±0.048	±9.3	±40.	±18.6	±0.058	±270.		
03005 + 3934	A 1530	127.9	0.4924	83.14	79.31	2020.7	0.739	78.72	4	···
(1d)		±7.2	±0.0038	±1.08	±1.70	±3.5	±0.053	±1.59		
05148 + 1232	HU 1224	1656.	2.3	105.0	100.	2111.	0.77	71.	5	···
(1e)		±8541.	±5.8	±9.9	±75.	±157.	±0.39	±155.		
20396 + 4035	STT 410 AB	1408.	0.751	126.	203.	1708.	0.67	63.	4	···
(1f)		±2242.	±0.016	±45.	±72.	±95.	±0.55	±102.		
21208 + 3227	STT 437 AB	1421.	2.5894	141.0	255.	1789.6	0.759	97.0	4	···
(2a)		±1274.	±0.0043	±13.8	±44.	±9.9	±0.043	±14.4		
21289 + 1105	STF 2799 AB	978.	2.098	131.0	187.	1735.	0.5297	133.	4	Popović (1987)
(2b)		±861.	±0.132	±12.6	±29.	±51.	±0.0106	±36.		
23595 + 3343	STF 3050 AB	717.	3.8557	61.85	185.22	1992.3	0.2154	116.4	4	Starikova (1977)
(2c)		±20.	±0.0013	±0.24	±0.77	±7.7	±0.0080	±6.7		

Table 4
Orbital Ephemerides

WDS Desig.	Discoverer Designation	2012.0 θ	2012.0 ρ	2014.0 θ	2014.0 ρ	2016.0 θ	2016.0 ρ	2018.0 θ	2018.0 ρ	2020.0 θ	2020.0 ρ	2022.0 θ	2022.0 ρ
00014 + 3937	HLD 60	168.6	1.290	167.9	1.298	167.2	1.305	166.5	1.311	165.8	1.317	165.1	1.322
00521 + 1036	STF 67	350.1	2.273	349.9	2.279	349.7	2.284	349.5	2.289	349.3	2.295	349.1	2.300
01467 + 3310	STF 158 AB	272.5	2.053	272.7	2.040	273.0	2.027	273.3	2.012	273.6	1.997	273.9	1.981
03005 + 3934	A 1530	74.5	0.262	76.2	0.245	78.3	0.214	81.4	0.159	91.3	0.066	244.2	0.059
05148 + 1232	HU 1224	114.5	1.031	114.2	1.028	113.8	1.025	113.4	1.022	113.1	1.019	112.7	1.016
20396 + 4035	STT 410 AB	4.1	0.863	3.9	0.864	3.7	0.866	3.6	0.868	3.4	0.869	3.2	0.871
21208 + 3227	STT 437 AB	19.6	2.415	19.3	2.425	19.0	2.435	18.7	2.445	18.4	2.454	18.1	2.464
21289 + 1105	STF 2799 AB	260.2	1.855	259.7	1.864	259.2	1.872	258.7	1.881	258.2	1.890	257.7	1.899
23595 + 3343	STF 3050 AB	337.6	2.301	338.9	2.347	340.1	2.392	341.3	2.437	342.4	2.481	343.5	2.525

3–4, 5–6, etc., through 13–14 give predicted values of θ and ρ, respectively, for the years 2012.0, 2014.0, etc., through 2022.0.

Notes to these systems follow.

WDS 00014 + 3937. Although its designation indicates this early K-dwarf pair was discovered by Holden, the first measure listed in the WDS is that of Burnham (1882); since that time the binary has completed just over half a revolution. This new orbit is similar to the solution of Heintz (1963), but was attempted due to runoff of the measures from that solution of nearly 50 years ago. Baize & Petit (1989) included HLD 60 in their catalog of doubles with a variable component.

WDS 00521 + 1036. Although this high-eccentricity pair has been observed for 180 years (Struve 1837), it has moved through barely 23° of its orbit during that period. The primary is of spectral type F8; based on the magnitude difference the secondary is about G2.

WDS 01467 + 3310. This is another long-period late-F/early-G Struve pair, although the double was apparently first observed by Herschel (1833). Fox (1915) measured two wide components at 55″ and 100″; observations are sparse, but proper motions suggest these two are optical companions.

WDS 03005 + 3934. This Aitken pair has moved through nearly a revolution since its discovery a century ago (Aitken 1908), but coverage is sparse. Angular motion should increase significantly over the next few years, as the pair approaches periastron in 2020. Spectral types are approximately F0 and F5, the latter estimated based on the *Hipparcos* magnitude difference.

WDS 05148 + 1232. This long-period pair, discovered by Hussey but apparently first measured by Aitken (Hussey 1907), is comprised of an A1V and a mid-A dwarf. Based on only 20° of coverage, this orbit is obviously very preliminary.

WDS 20396 + 4035. This pair of B8 giants was apparently first observed by Mäedler (1844), although the designation suggests it as one of Otto Struve's discoveries. The Struve family can claim some ownership of this system, however; the C component was first measured by Otto in 1851 (Struve 1878), while the D component was measured by Otto's grandson, George, in 1923 (Struve 1963). The physical/optical nature of these two wide components is unknown.

WDS 21208 + 3227. This is another Otto Struve pair apparently first observed by Mäedler; the primary is G4V, the secondary perhaps a couple subclasses later. Faint wide C and D components both appear to be optical in nature.

WDS 21289 + 1105. This is an extremely well-observed pair, with well over 400 observations since 1855 (South, cited by Lewis 1906). Components are both mid-F dwarfs; a faint companion at over 2′ separation is not physically associated with this pair. Measures appear to be running off from the Popović (1987) solution.

WDS 23595 + 3343. This Frederick Struve pair can claim over 600 observations, going back to a 1777 observation by Mayer (1784) and two other 18th century observations by William Herschel (cited by Lewis 1906) and de Lalande (1831). Despite this long observing history the pair has completed only ∼150° of orbital coverage. A faint C component at 80″ is optical.

4. CONCLUSIONS

We have presented 299 additional speckle observations obtained at the Strand 61 inch reflector, as well as nine new or improved orbital solutions based in part on some of these new data. The Strand telescope appears to be well suited to these types of observations, allowing us to resolve pairs a factor of two closer in separation than possible with the Clark 26 inch in Washington. While the Clark still maintains significant advantages as a local telescope dedicated solely to speckle work, the Flagstaff facility remains an attractive option for occasional observations of neglected closer binaries.

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